JOINT PATTERNS WITHIN THE EPICENTRAL AREA OF THE 1982 MIRAMICHI EARTHQUAKE

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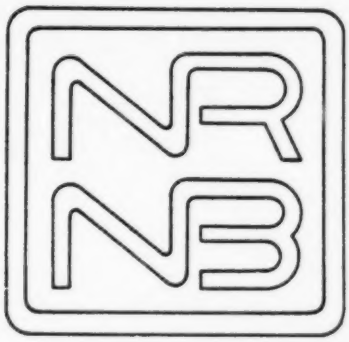
1983

JOINT PATTERNS WITHIN THE EPICENTRAL AREA OF THE 1982 MIRAMICHI EARTHQUAKE



Mineral Resources Division
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Copies available by contacting:

Mineral Resources Division
Department of Natural Resources
P. O. Box 6000, Fredericton, N. B.
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Report No.: Open File Report 83-13
Author: L. R. Fyffe
Cover: Tim Fevens
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INTRODUCTION

During the summer of 1982, J.E. Adams of the Earth Physics Branch (EPB) and J.L. Wallach of the Atomic Energy Control Board (AECB) noted a post-glacial offset along a north-trending fracture in a small exposure of diorite on a logging road in the epicentral area of the January, 1982 Miramichi earthquake (Stevens, 1983). The trend of this fracture and the offset across it are in agreement respectively with the geometry and kinematics inferred for the earthquake zone from the fault plane solutions (Wetmiller et al., in press).

In the fall of 1983, the AECB and the Geological Survey of Canada (GSC) engaged Lockhart Exploration Services of Fredericton, New Brunswick to clear the overburden from a 30 m X 100 m area surrounding the above exposure in order to investigate the extent of this fracture. The glacial till, which was about one metre thick, was removed by a bulldozer and the bedrock, a generally massive, sheeted diorite, was hosed off with water pumped from Indian Lake. The cleaning operation took about two weeks.

J.J. Chandra of the New Brunswick Geological Surveys Branch surveyed in a 5 m X 5 m grid over the cleared area. Elevations for each grid point were determined relative to a pin placed in the original diorite outcrop on the northern side of the clearing (Plate 83-77). The pin is part of a levelling network established in the area by the Survey Engineering Department of the University of New Brunswick for the purpose of monitoring relative horizontal and vertical displacements that may arise

from earthquake activity.

The writer mapped the exposure on a scale of 1 cm = 1 m (Plate 83-78) with the assistance of A.G. Pronk. The surrounding geology has been described by Fyffe (1982).

GLACIAL FEATURES

Glacial striations which are clearly displayed on the freshly exposed bedrock vary in trend from 90° on the northern part of the exposure to 105° in the south. Lunate fractures on a polished surface at the northern end of the outcrop show that ice movement was to the east.

Plucking of subhorizontal sheeting in the diorite on the lee side of glacial movement (eastern side) has produced a step-like pattern that descends to the southeast along large, crescent-shaped fractures roughly following the northeast-trend of a steep joint set.

JOINT DESCRIPTION

Six sets of joints have been recognized during the mapping. They are discussed below in order of relative age as established by their observed cross-cutting relationships.

Set 1: These relatively rare joints, seen only on the northern flank of the exposed area, trend north (350° to 10°) and dip between 30° and 75° to the west with dips of 40° to 50° being the most common (Figure 1). Slickensides on epidote-coated joint surfaces rake 75° to the south. A joint of this set has been

Figure 1. West-dipping joint of Set 1 showing post-glacial offset. (Relief in foreground is produced by glacial plucking. Compass in this and subsequent photographs is oriented north.).

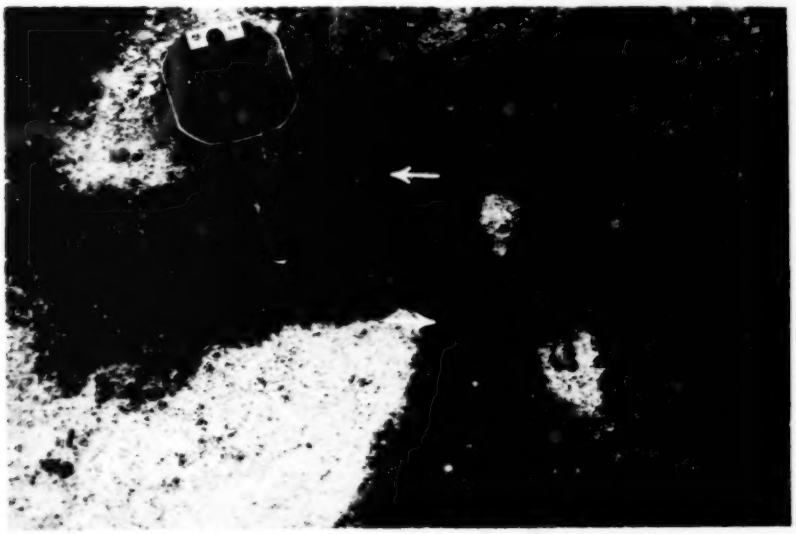

Figure 2. Set 1 joint (arrows) offset left-laterally by quartz stringer in Set 2 joint.

slightly offset left-laterally by Set 2 described below (Figure 2).

The most prominent joint of Set 1 occurs through the centre of the northern portion of the area (Figure 1). Originally this joint was exposed only in an outcrop on a logging road where a 2 cm upthrust of its hanging wall could be observed displacing glacial striations. he overburden had been specifically removed from the area so that this feature could be traced along strike. The fracture, which was found to continue some 20 m south of its initial exposure near the survey pin, was recognized both in the uppermost of the gently north-dipping sheets as well as in the underlying sheets. However, displacement across the fracture was present only in the uppermost sheet which extends for just 5 m south of the survey pin. Such an effect may have resulted from glacial unloading, frost heaving, or post-glacial tectonic stress.

Set 2: This well developed set of vertical joints, generally spaced at intervals of 2 to 3 m, trends east-southeast (120°). Quartz stringers ranging in thickness from 1 to 5 cm (Figure 3) and less common aplitic dykes from 2 cm to 10 cm thick (Figure 4) fill the fractures. An open crack with a parting of about 1 mm separates a quartz stringer from its wall rock in the northwestern part of the exposure (Figure 5).

Irregular granite veins in the diorite are generally offset from 1 to 4 cm left-laterally in the southern half of the area (Figure 6) but one joint through the central part displaces a vein by 30 cm in a right-lateral sense (Figure 7). Veins are not

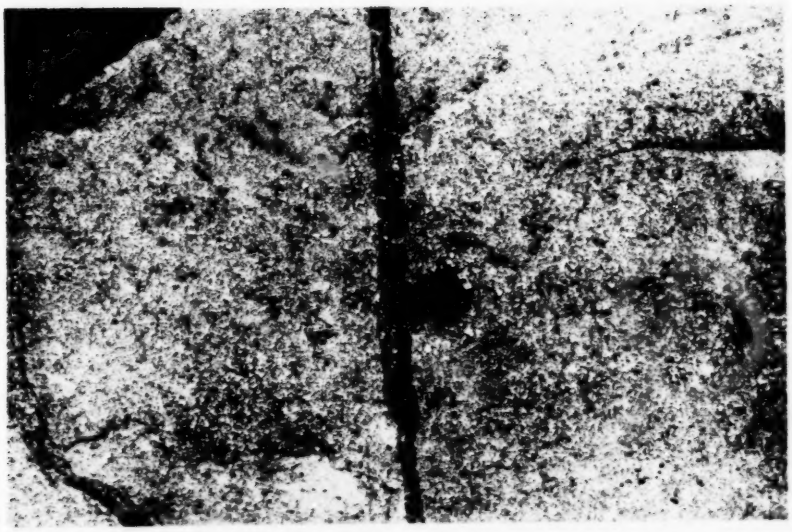

Figure 3. Quartz stringer in Set 2 joint.

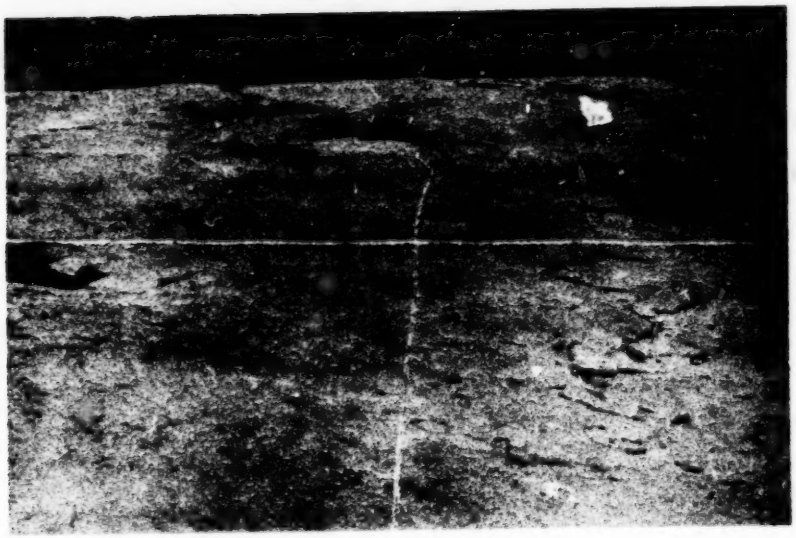

Figure 4. Aplite in Set 2 joint.

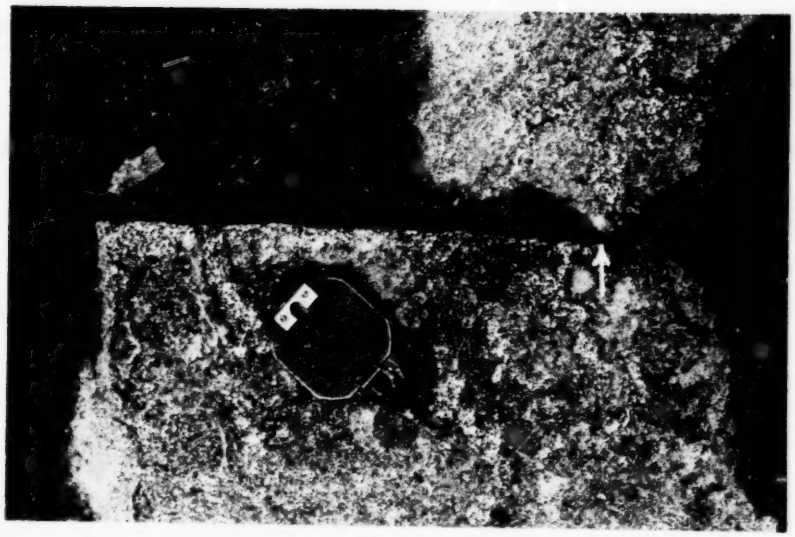

Figure 5. Open fracture (arrow) along wall of quartz stringer in Set 2 joint.

Figure 6. Granite vein offset left-laterally (arrow) by Set 2 joint.

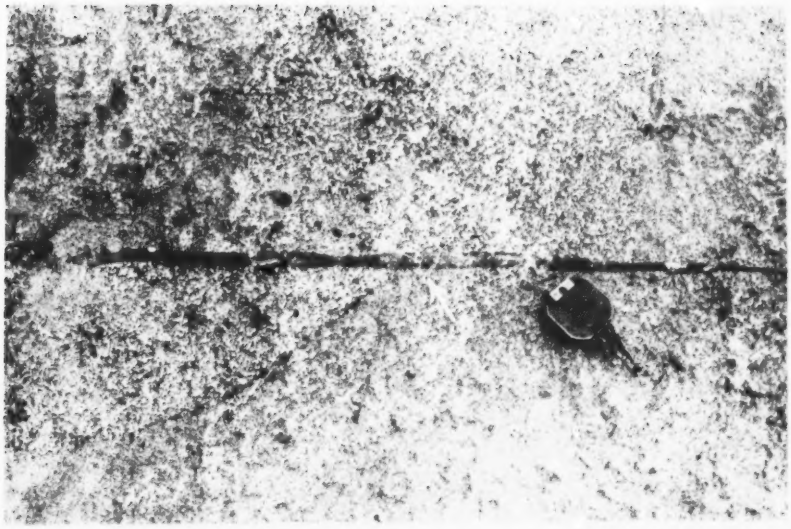

Figure 7. Granite vein offset right-laterally (arrow) by Set 2 joint.

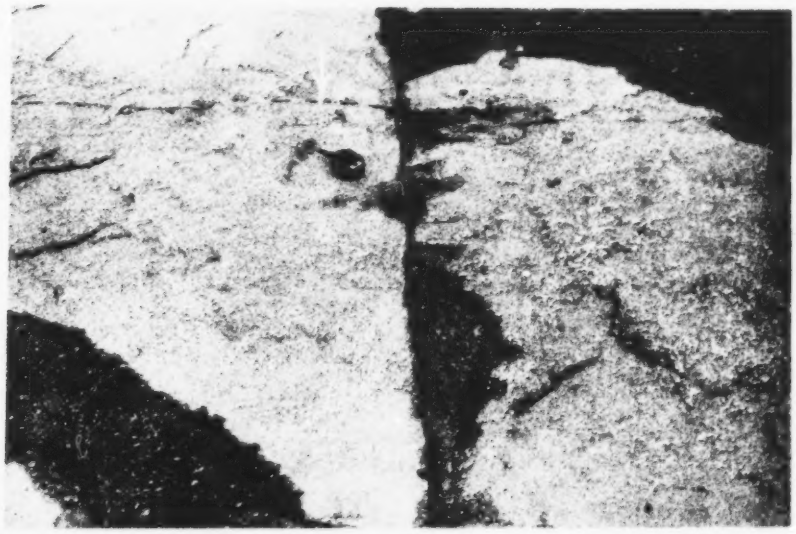

Figure 8. Northeast-trending Set 3 joint perpendicular to quartz stringer (arrow) in Set 2 joint.

offset in the northern part of the area but, at one locality a joint of Set 1 shows 1 cm of left-lateral displacement (Figure 2). This movement on the Set 2 fracture obviously occurred later than the formation of Set 1; assuming that the movement was more-or-less contemporaneous with, rather than much later than the development of Set 2 would indicate that Set 2 joints formed after Set 1.

Set 3: Vertical joints trending to the northeast (20° to 50°) roughly at right angles to Set 2 are best developed in the southern part of the area (Figure 8). They are generally spaced at 1 to 4 m intervals. Glacial plucking along the southeastern side of one fracture of this set, located in the southeastern corner of the area, has created 140 cm of topographic relief. No veining material was observed in any of these fractures; rarely the fractures are open with a separation of 1 to 2 mm. Commonly the intersections of the perpendicular sets are not displaced but on the east side of the exposure, a joint of Set 2 is offset 1 cm right-laterally by one of the Set 3 joints (Plate 83-78).

Set 4: Joints trending northward (345° to 0°) and dipping east are prevalent in the northern portion of the exposed area (Figure 9). A single fracture of this set occurs in the southwestern corner. Dips range from 50° to 80°, but those between 60° and 70° are most common. The joints, spaced at intervals of 2 to 6 m, are invariably filled with epidote and chlorite. Slickensides on exposed joint surfaces rake 25° to the south (Figure 10).

This set consistently offsets both Set 2 and Set 3 in a

Figure 9. East-dipping joint of Set 4.

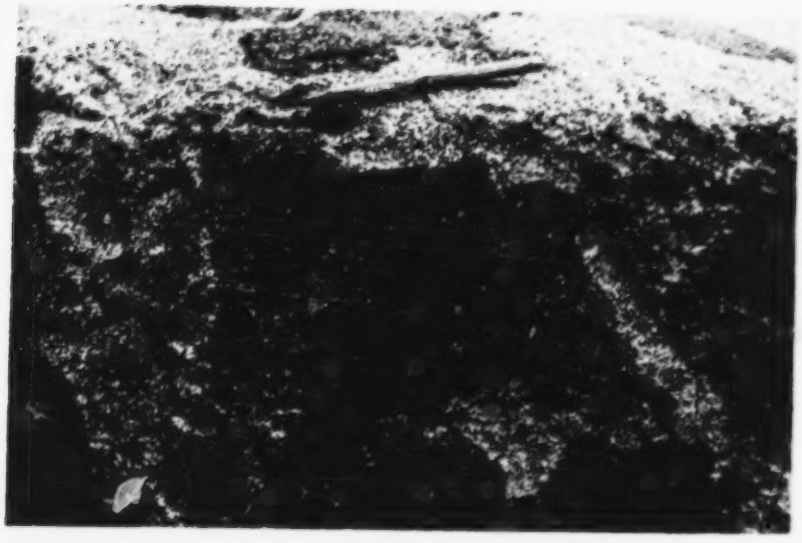

Figure 10. Subhorizontal slickensides on Set 4 joint surface.

Figure 11. Quartz stringer (arrows) in Set 2 joint offset right-laterally by Set 4 joint.

Figure 12. Aplite (arrows) in Set 2 joint offset right-laterally by Set 4 joint.

right-lateral sense (Figures 11 and 12). Displacement of Set 2 along one fracture of Set 4, located in the northwestern part of the exposure, varies over a distance of 55 m along strike from 35 cm in the north to 6 cm near its southern terminus; decreasing displacement can be explained by bifurcation of the fracture. Tension gashes along these fractures are consistent with right-lateral movement (Figure 13). About 4 cm of post-glacial upthrusting occurs along a 3 m section of the northern part of this fracture (Figure 14).

Set 5: Rare joints trending east-northeasterly (60° to 70°) and dipping between 55° and 65° to the northwest are well displayed in the southern part of the area (Figure 15). Glacial scouring on the northern side of the most persistent of these fractures has produced a topographic relief of 160 cm. Another of these fractures displaces a joint of Set 2 for 1 cm left-laterally (Figure 16). No offset was observed between Set 4 joints and Set 5 joints which are, therefore, assumed to have formed at the same time. Several poorly developed fractures in the northeastern corner of the area have similar trends to those of Set 5.

Set 6: Subhorizontal sheeting, spaced at intervals of about 10 cm, has dips of between 5° and 18° to the north roughly parallel to the topographic slope of the exposure. The northern end of the outcrop is approximately 10 m below the southern. Glacial plucking of these sheets occurs principally along the southeastern side of steep, northeast-trending joints, i.e. on the lee side of the glaciation.

Figure 13. Tension gashes (arrow) oriented at an angle to Set 4 joint. Note offset of quartz stringer (vertical in photograph) in Set 2 by Set 4 joint (horizontal in photograph).

Figure 14. Post-glacial offset on Set 4 joint.

Figure 15. Northwest-dipping joint of Set 5.

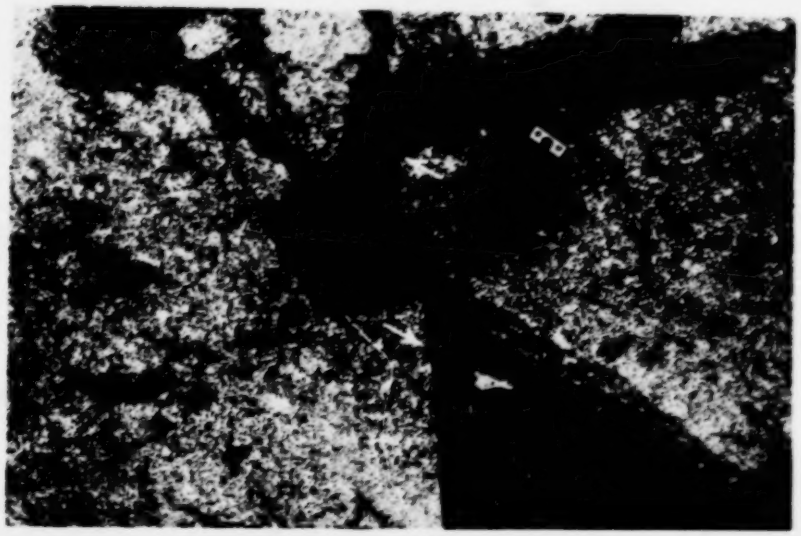

Figure 16. Set 2 joint offset (arrows) offset left-laterally by Set 5 joint.

A narrow remnant of one of these plucked sheets, located in the north-central part of the area, buckled about one week after removal of the overburden. An open space of 8 cm now separates the highest point of the arched sheet from the underlying layer. An irregular, north-trending crack has broken through the axis of the arch (Figures 17 and 18).

ORIGIN OF JOINTS

The formation of the six joint sets can be explained in terms of three joint patterns: the first pattern comprises Sets 1, 2, and 3; the second comprises Sets 4 and 5; and the third consists of Set 6.

Joints of Set 2 are filled with aplite and quartz which indicate the existence of a tensile environment before complete consolidation of the plutonic host rocks. Set 3 joints are perpendicular to Set 2. Such an orthogonal system can be interpreted as planes of extension (Set 2) and release (Set 3) formed respectively parallel and perpendicular to the direction of maximum compressive stress (west-northwest and east-southeast) known to have existed during the mid-Devonian Acadian Orogeny (cf. Lajtai and Stringer, 1981).

Set 1 is apparently the oldest set as indicated by cross-cutting relationships. Slickensides on the moderately dipping surfaces of the set show movement is largely dip-slip. It is conceivable that these fractures formed under approximately the same orientation of maximum compression as Set 2 and 3 but with

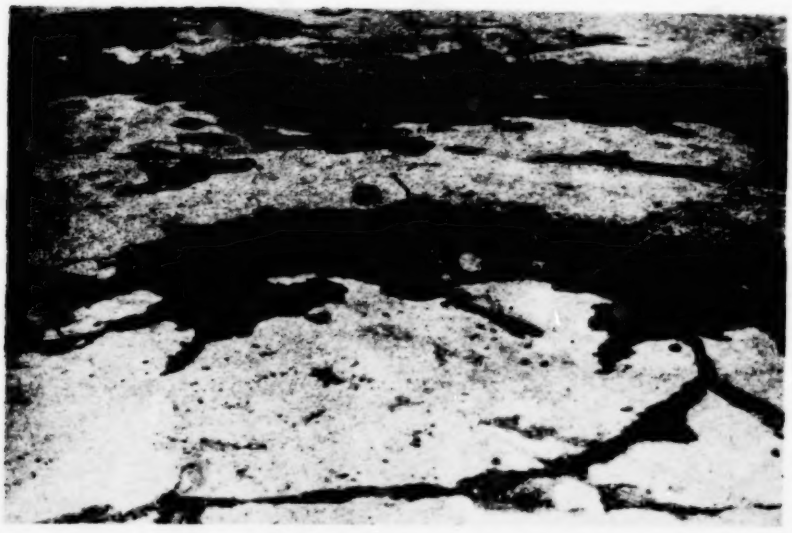

Figure 17. Arched sheeting in diorite. Note crack just to right of compass.

Figure 18. Side view of arched sheet.

the intermediate stress axis horizontal rather than vertical as during the later joint development (see diagram "A" of Figure 19).

Joints of Set 4 show considerable right-lateral offset and slickensides prove movement to be largely strike-slip. The trend of the comparatively more poorly developed joints of Set 5 is oriented at about 70° to that of Set 4. This, together with their slight left-lateral offset, suggests that Set 5 has a conjugate shear relationship to Set 4. A subhorizontal maximum compressive stress oriented in a south-southwest (north-northeast) direction with a subvertical intermediate stress axis would be compatible with this fracture pattern. (see diagram "B" of Figure 19). Strike-slip regimes are a characteristic feature of Carboniferous tectonics in the Northern Appalachians (Webb, 1969) and Set 4 and 5 may have originated at this time.

The sheeting of Set 6, which is parallel to the land surface, is an erosional unloading phenomenon. The recent popping up of one of these sheets suggest a present maximum compression in an east-west orientation.

DISCUSSION

First motion studies of the January 9th earthquake yielded orthogonal planes trending 15° with a dip 50° west and 332° with a dip 48° east. Furthermore, a study of the aftershock distribution outlines a plane trending 17° with a dip of 42° west at depth varying to 345° with a dip of 78° west at the surface as

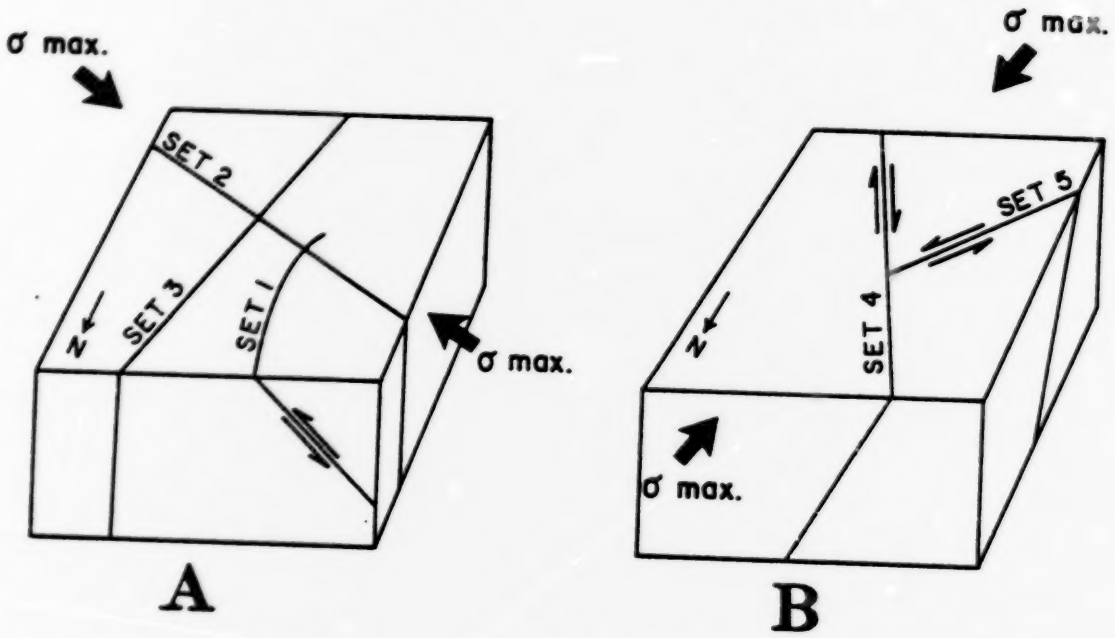

Figure 19. Schematic block diagrams showing orientation of maximum compressive stress (see text for explanation).

the break responsible for the main shock (Wetmiller et al., in press). As noted earlier, joints of Set 1 are oriented roughly parallel to this west-dipping direction. Post-glacial upthrusting on Set 1 appears to be a surface phenomenon that may only coincidentally reflect the motion predicted for the earthquake-related fault.

Aftershock distributions also indicate involvement of a second plane trending 336° with a dip of 47° east at depth varying to 14° with a dip of 63° east at the surface. This postulated fault nearly coincides with the auxiliary plane obtained from the first motions of the main shock. The two predicted faults then are not likely to have formed as conjugate shears which would be expected to subtend an angle of 60° instead of the 90° found from the aftershock distribution. The orientation of the second fault is in good agreement with the east-dipping Set 4 joints which have also been shown from cross-cutting relationships not to be conjugate to Set 1. Joints of Set 4 also show limited post-glacial movement.

Set 1 and Set 4 joints have existed in central New Brunswick for a few hundred million years. Early movement on Set 1 fractures was dip-slip, whereas offset on Set 4 was largely strike-slip. Reactivation of these independent fractures under east-west compression would offer one explanation for the high-angle thrusting associated with the Miramichi earthquake.

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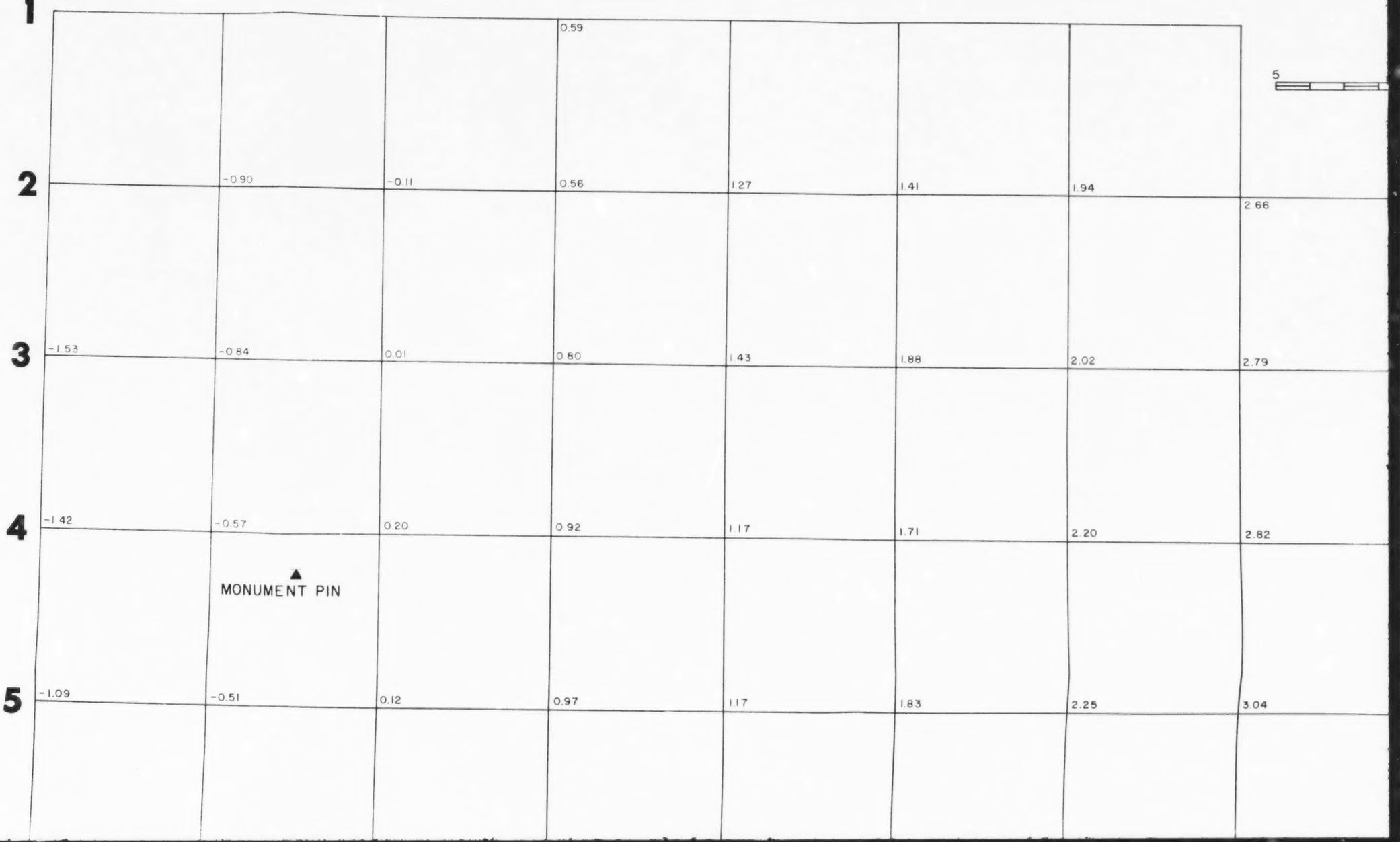
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GRID FOR PLATE 83-78

0.56 — *Elevation in metres relative to pin*

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2.82	3.41	3.83	4.54	4.96	5.19	5.59	5.53	5.54	6.12
3.04	3.43	4.05	4.51	5.04	5.54	5.82	6.37	6.59	6.18

TE 83-78

	6.68	7.52	7.39	7.93	8.65	9.06	8.99
	6.12	7.43	8.14	8.69	8.32	8.71	8.75 9.21
	6.18	7.65	8.22	8.72	9.23	8.66	8.88 9.59

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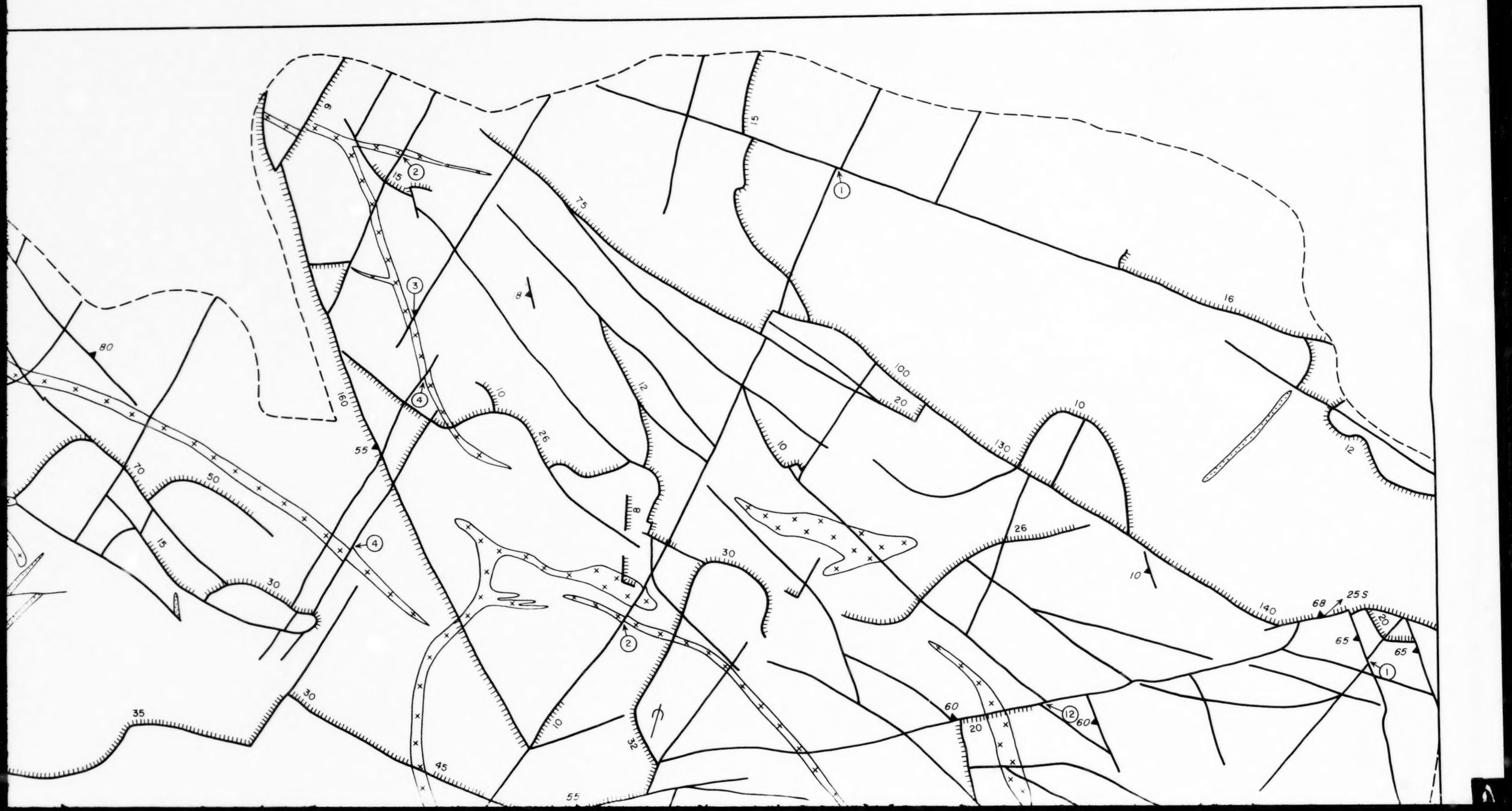
PLATE 83-78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7	-0.98	-0.32	0.90	1.25	1.57	2.41	2.60	3.24
8								

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	3.27	3.99	4.59	5.27	5.75	5.72	6.22	6.44	6.69	6
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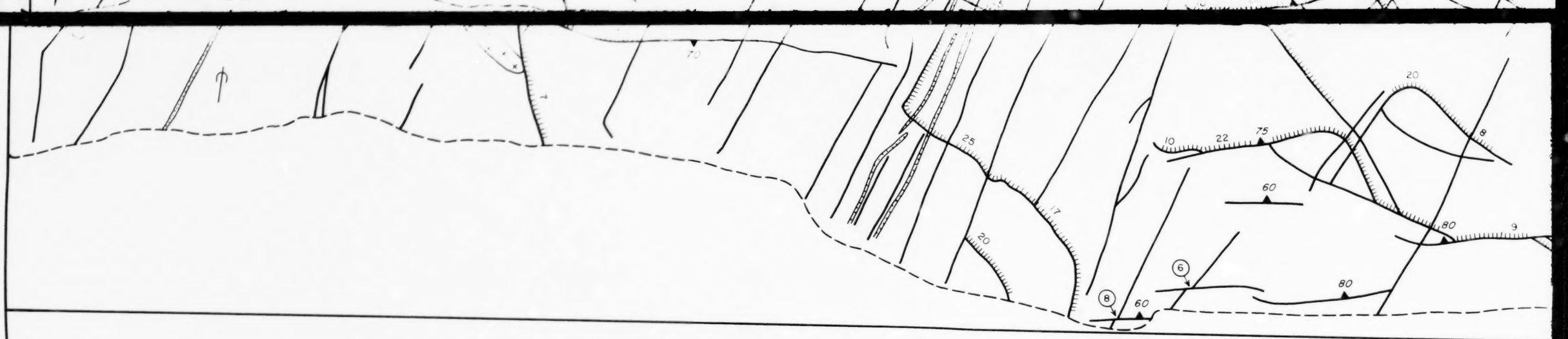
4	6.69	6.86	7.94	8.73	9.49	9.82	9.95 9.88
	7.31	7.70	7.96	8.44	8.99	9.49	9.63 9.93
				8.21	8.47	9.42	9.16 9.45

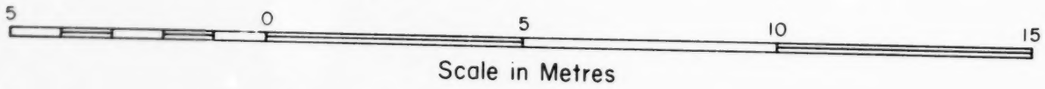
Q R S T U V W X

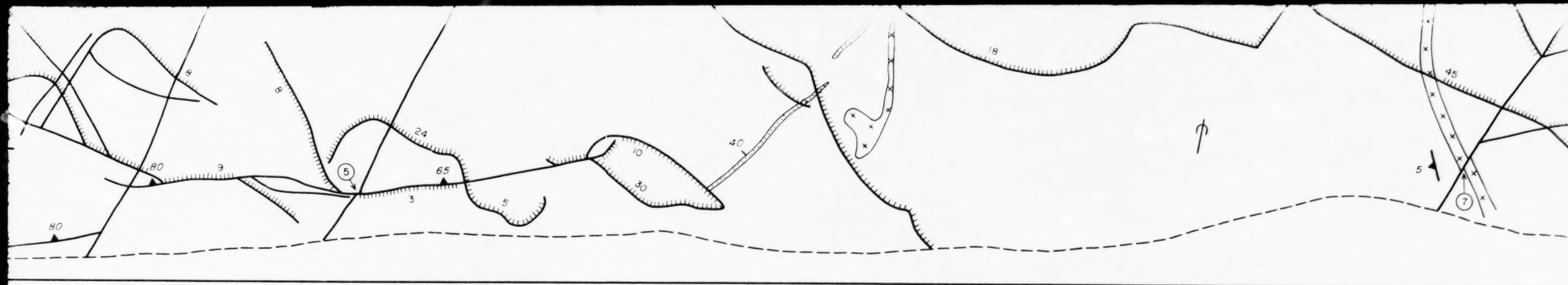
J. CHANDRA, 1983



GEOLOGY OF CLEARED DIORITE EXPOSURE IN THE EPICENTRAL AREA OF THE 1982 MIRAMICH EARTHQUAKE

by: L. R. Fyffe, A.G. Pronk

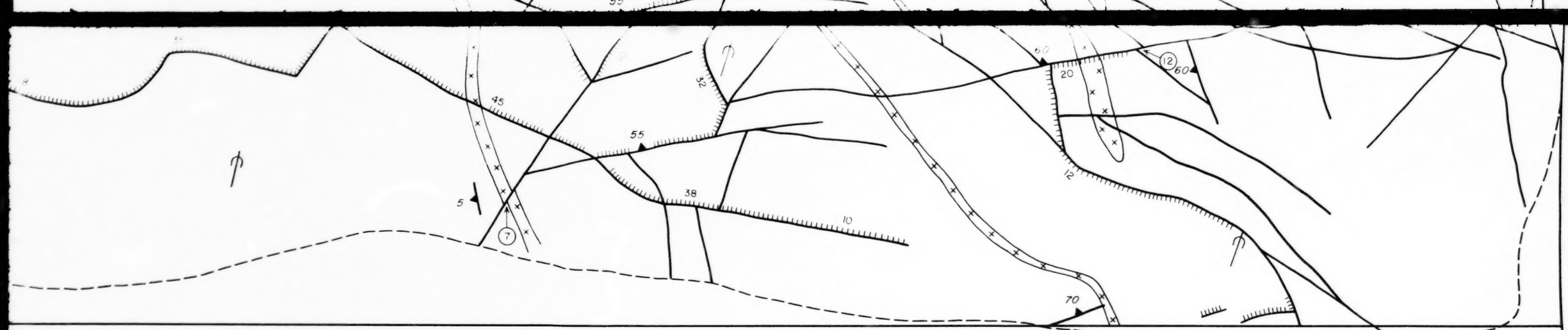




OSURE IN MIRAMICHI

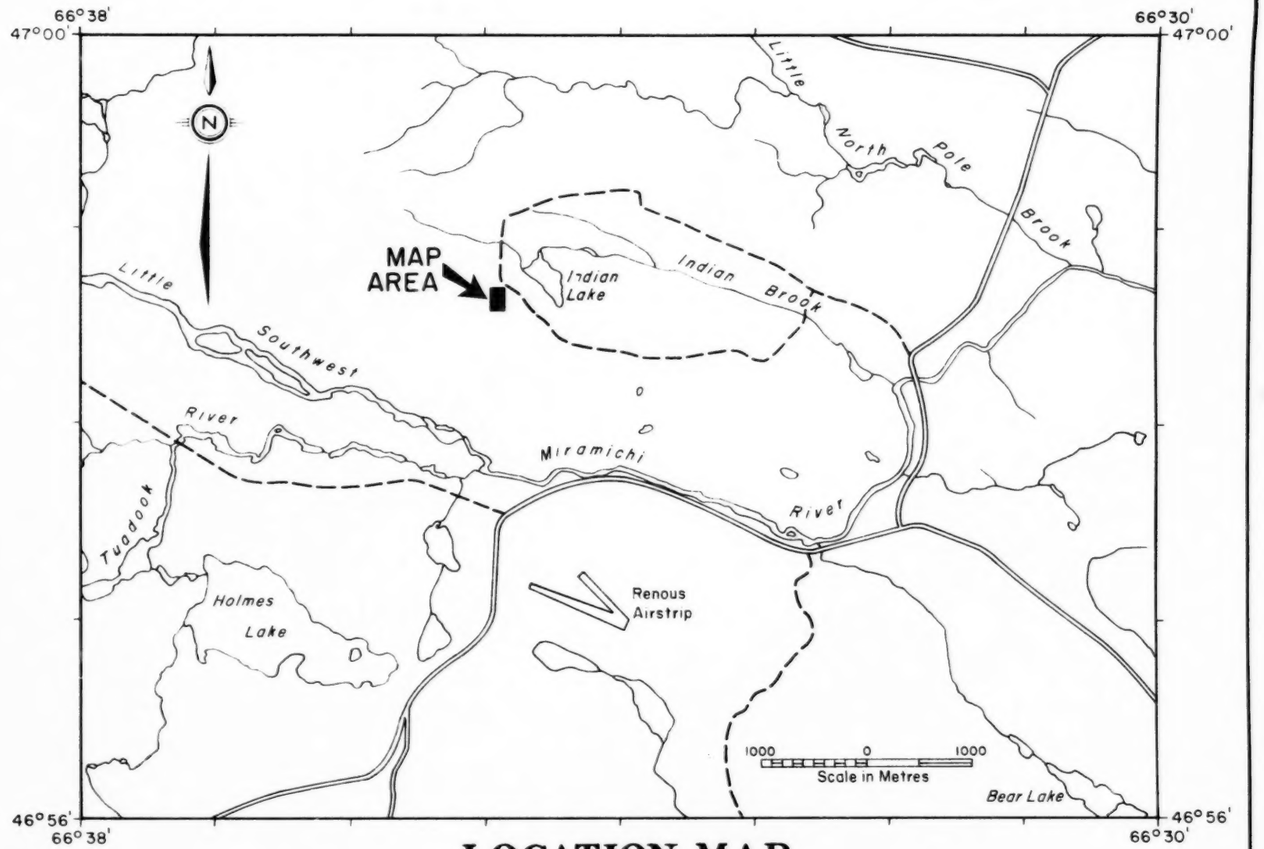
Legend

- Joints (vertical, inclined, subhorizontal) — 65, 10
- Lateral offset along joints in centimetres — 5
- Topographic relief along joint with hatching on lower side. Number gives amount of relief in centimetres. Relief due to post-glacial movement shown in box. — 5
- Rake of slickensides — 25
- Tension gash
- Glacial striations
- Glacial lunate fractures
- Granite vein
- Aplitic dyke (dip indicated if other than vertical) — 40
- Limit of exposed area
- Survey pin



end

- Glacial striations
- Glacial lunate fractures
- Granite vein
- Aplitic dyke (dip indicated if other than vertical!) — 40
- Limit of exposed area
- Survey pin



LOCATION MAP

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